# Technical Efficiency in Organic and Conventional Farming: Evidence form Italian Cereal Farms

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**Abstract**

*A stochastic frontier production model was applied to estimate technical efficiency in a sample of Italian organic and conventional cereal farms. The main purpose was to assess which production technique revealed higher efficiency. Statistical tests on the common production function model suggested that the two cultivation methods might lie on different frontiers. Separate analyses of two sub-samples (93 and 138 observations for organic and conventional farms, respectively) found that conventional farms were significantly more efficient than organic farms, with respect to their specific technology (0.902 vs. 0.831). Analysis also estimated that efficiency plays a crucial role into the factors affecting productivity in the organic process. Some policy implications can be drawn from these findings.*

**Keywords**: *Organic farming, Comparison analysis, Cereal-growing, Technical efficiency, Stochastic frontier production models, Italy*

## Introduction

Since the early 1990s, organic farming has become a significant element within the Common Agricultural Policy (CAP) of the European Union (EU). From an EU viewpoint, it serves some of the main objectives of the CAP as it stands today: improving food safety, promoting food quality, environmental protection, reduction in agricultural output surplus and re-orientation of agriculture towards the market (European Commission, 2000). The Mid-Term Review Reform seems to enforce the role of organic farming into the CAP, given that some of the main proposed objectives of the Reform are fully served by organic farming (European Commission, 2002a). An evidence of this increasing role is the recent publication of an *Action Plan* for organic farming that outlines some guidelines for the promotion of adequate programmes in the next CAP and, principally, in rural development policies. (European Commission, 2004)[1]. The Plan urges to a greater policy effort on organic farming, applying specific measures in the organic sector, enforcing the role in the regional '*Agri-environmental programmes'* and improving the efficacy of horizontal measures.

It is clear, however, that every European effort to promote organic farming could be invalidated if individual farms do not reach adequate productive and efficiency levels (Lampkin and Padel, 1994; Offermann and Nieberg, 2000). This means that any policy

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effort in supporting conversion to organic farming needs an adequate level of efficiency of individual farms to achieve success (Tzouvelekas et al., 2002a). This would imply that organic farming must strive to be efficient both productively and economically.

Therefore, development of organic methods raises significant research questions related to productivity and efficiency. In spite of the relevance of these topics, literature on the performance of organic farming is still insignificant, primarily, due to the relative unavailability of data on organic farms (Oude Lansink et al., 2002; Zanoli et. al, 2002). Above all, little attention has been paid to efficiency. Studies on productivity are certainly relevant, but also efficiency analysis provides useful information on the convenience or otherwise of adopting organic techniques (Cembalo and Cicia, 2002). In comparative studies between organic and conventional farms, efficiency analysis is particularly suitable for assessing the farmers' relative ability in optimizing internal resources. Furthermore, the utilization of an efficiency estimation approach is advisable in studies aimed at providing policy indications (Coelli et al., 2002; Lovell, 1995).

Only in recent years has research literature proposed some comparative studies on technical and economic efficiency aimed at assessing efficiency differentials between organic and traditional farming (Tzouvelekas et al., 2001a, 2001b, 2002a, 2002b; Oude Lansink et al., 2002; Sipiläinen and Oude Lansink, 2005). These studies obtained controversial which technique reveals higher efficiency.

The study proposed in this paper aimed to estimate technical efficiency in a sample of Italian organic cereal farms. Using a parametric approach, a comparative analysis with sample of conventional farms was carried out to assess which method was more technically efficient.

## Methodology

Generally, Technical Efficiency (TE) is defined as the measure of the ability of a firm to obtain the best production from a given set of inputs (*output-increasing oriented)*, or as the measure of the ability to use the minimum feasible amount of inputs given a level of output (*input-saving oriented*) (Greene, 1980; Atkinson and Cornwell, 1994)[2]. Consequently, technical inefficiency is defined as the degree to which firms fail to reach the optimal production.

Farrell (1957) proposed a TE firm measure by comparing its observing output to the best production output, *i.e.* the output which could be produced by a *fully efficient* firm, given the same bundle of inputs. Basing on this model, several procedures have been proposed in literature to estimate TE. This section is dedicated to the Stochastic Frontier Production (SFP) Function Models, originally and independently proposed by Aigner et al. (1977) and Meeusen and van der Broeck (1977)[3]. In the SFP models the production frontier is specified which defines output as a stochastic function of a given set of inputs[4]. It concerns that the error term ε may be separated in two terms: a random error and a random variable explanatory of inefficiency effects:

$$y_i = f(x_i, \beta) \cdot \exp(\varepsilon) \quad \text{and} \quad \varepsilon = (v_i - u_i) \qquad i = 1,2,\ldots N \tag{1}$$

where $y_i$ denotes the level of output for the $i$-th observation; $x_i$ is the row vector of inputs; $\beta$ is the vector of parameters to be estimated; $f(\cdot)$ is a suitable functional form for the frontier; $v_i$ is a symmetric random error assumed to account for measurement errors and other factors not under the control of the firm; and $u_i$ is an asymmetric non-negative error term assumed to account for technical inefficiency in production. The $v_i$'s are usually assumed to be independent and identically distributed $N(0, \sigma_v^2)$ random errors, independent of the $u_i$'s that are assumed to be independent and identically distributed and truncations (at zero) of the normal distribution $|N(0, \sigma_u^2)|$. The MLE (Maximum Likelihood Estimation) of (1) consents to estimate the vector $\beta$ and the variance parameters $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u / \sigma_v$; where $\gamma$ varies between 0 and 1.

As consequence, $TE_i = \exp(-u_i)$ and the frontier production (maximum achievable level of output) is computed as its observed production divided by its $TE_i$ value.

Most of the SFP Function Models proposed in literature are inappropriate to estimate the inefficiency effects caused by factors that affect efficiency. In order to estimate these effects, some authors proposed a *two-stage* method, in which the first stage consists in TE estimation using a SFP approach, and the second stage involves the specification of a regression model that relaxes TE with some explanatory variables (Pitt and Lee, 1981; Kalirajan, 1982; Parikh and Shah, 1994). A *one-stage* SFP model in which the inefficiency effects ($u_i$) are expressed as a function of a vector of observable explanatory variables was proposed by Kumbhakar et al. (1991), Reisfschneider and Stevenson (1991), Huang and Liu (1992). In this model, all parameters – frontier production and inefficiency effects – are estimated simultaneously. This approach was adapted by Battese and Coelli (1995) to account for panel data. Furthermore, they suggested to use an *one-stage* approach because the *two-stage* estimation procedure is inconsistent in it's assumption regarding independence of the inefficiency effects[5].

With regards cross-sectional data applications, the inefficiency term $u_i$ in the Battese and Coelli (1995) model has a truncated (at zero) normal distribution with mean $m_i$:

$$u_i = m_i + W_i \quad \text{and} \quad m_i = \mathbf{Z}(z_i, \delta) \quad i = 1,2,\ldots, N \qquad (2)$$

where $W_i$ is a random error term which is assumed to be independently distributed, with a truncated (at $-m_i$) normal distribution with mean zero and variance $\sigma^2$; $\mathbf{Z}$ is the vector (Mx1) of the $z_i$ firm-specific variables of inefficiency; and $\delta$ is the (1xM) vector of unknown coefficients associated with $z_i$. In this way, we are able to estimate inefficiency effects arisen from the $z_i$ explanatory variables[6].

## Data and empirical model

The information used in this study was collected from cross-sectional data of Italian specialized cereal farms. All the observed farms were in Sardinia and they participated in the official Farm Accountancy Data Network (FADN) during 2001 and 2002. It is common opinion that FADN represent a suitable database for studies on the organic sector and efficiency analyses (Oude Lansink et al., 2001; Scardera and Zanoli, 2002).

This study focused on Sardinia because the region plays an important role into the Italian organic agriculture. Based on the Agricultural Census 2000, the Sardinian land area under organic crops amounted to 27.7% of the national organic area (ISTAT, 2002). The 235,000 hectares cultivated under organic management corresponded to about 23% of total agricultural regional land. In the Sardinian organic sector, cereal-growing occupies a significant position. About 23,000 hectares of cereals were cultivated under organic technology, equal to 15.8% of the overall Sardinian area under cereals.

The dataset consists of 231 observations. Among these, 93 farms had switched to organic cereal-growing. In the remaining 138 observed farms, cereals were cultivated with conventional methods[7]. All selected organic farms were '*in maintenance*' phase. Furthermore - as illustrated in Table 1 - organic and conventional farms showed similar input endowment (*e.g.* land area was equal to, on average, 8.7 and 8.5 ha for organic and conventional farms, respectively). This feature permits to minimize the risk that possible difference in productivity and/or in technical efficiency between organic and conventional practices are given by sensitive differences in the farms structure. The farms are specialized in durum wheat (65 and 52 under conventional and organic technology, respectively) oats (40 conventional and 24 organic farms) and barley (33 conventional and 17 organic farms) cultivation.

In this study, we assumed a Translog functional form as frontier technology specification for the farms. Using the Battese and Coelli (1995) procedure, the Translog SPF is specified as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{6} \beta_j \ln x_{ji} + \frac{1}{2}\sum_{j\leq}^{6} \sum_{k=1}^{6} \beta_{jk} \ln x_{ji} \cdot \ln x_{ki} + D_{o/c} + D_{dw} + D_o + D_b + (v_i - u_i) \quad (3a)$$

where the subscript $i = 1,2\ldots N$ denotes the observation for the $i$-th firm and $j, k = 1,2\ldots J$ stand for used inputs. The dependent variable ($Y$) represents the value (in euro) of total cereals produced by the $i$-th firm. The aggregate inputs, included as variables of the production function, are 1) $X_1$ the total *Land* area (hectares) devoted to cereals by each farm each; 2) $X_2$ the expenditure (euro) for *Seeds*; 3) $X_3$ the expenditure (euro) for *Fertilizers*, pesticides, etc; 4) $X_4$ the total amount (euro) of *Capital* (financial, machineries, building, etc); 4) $X_5$ the total amount (hours) of *Labour*; 4) $X_6$ the total amount (euro) of *Other expenditures*.

**Table 1.** Summary statistics of the observed sample

| Variable | Conventional *(138 farms)* | | Organic *(93 farms)* | |
|---|---|---|---|---|
| | ***Mean*** | ***s.d.*** | ***Mean*** | ***s.d*** |
| Output (*euro*) | 8,299.38 | 8,003.78 | 9,275.42 | 7.155.40 |
| Land area (*hectares*) | 8.73 | 4.82 | 8.49 | 5.10 |
| Seeds expenditure (*euro*) | 536.19 | 560.91 | 516.50 | 508.09 |
| Fertilizers, pesticides (*euro*) | 449.50 | 420.28 | 617.54 | 622.84 |
| Machineries, buildings, (*euro*) | 15,931.74 | 12,920.45 | 17,153.07 | 16,620.44 |
| Labour (*hours*) | 483.88 | 390.95 | 449.07 | 433.96 |
| Other expenditures (*euro*) | 655.86 | 587.77 | 531.42 | 501.39 |

As a first step, we assumed a unique technological frontier for both organic and conventional farms. The purpose was to test the hypothesis on technological homogeneity between organic and conventional cereal-growing. Most of the studies have adopted two separate technologies for organic and conventional processes. Basic assumption is that organic farming achieves minor productivity and the two techniques lie on different frontiers. It is our opinion that the assumption on technological homogeneity between organic and conventional methods needs to be tested to better fit the efficiency model. It is a critical point because - as showed by Oude Lansink et al. (2002), Ricci Maccarini and Zanoli (2004) and Sipiläinen and Oude Lansink (2005) – refereeing efficiency analysis to a unique reference frontier and/or to separate frontiers could drive to more realistic interpretation of TE. Thus, the original (pool) model includes a *dummy* variable ($D_{o/c}$) that reflects the agronomic technique (organic = 0; conventional = 1)[8].

Furthermore, the rationale underlying of the proposed model is that the three observed cereal species (durum wheat, oats, barley) might lie on different production frontiers. For this reason, the common production function involves three *dummy* variables ($D_{dw}$, $D_o$, $D_b$) linked to the cereal species.

The inefficiency effects model has the following form:

$$u_{it} = \delta_0 + \delta_1 Z_{i1} + \delta_2 \ln Z_{i2} + \delta_3 Z_{i3} + \delta_4 Z_{i4} + W_i \tag{3b}$$

Explanatory variables of the inefficiency effects were represented by 1) $Z_1$ the *Age* of the farmer; 2) a *dummy* variable $Z_2$ that reflects the *Gender* of the farmer (0 = female; 1 = male), 3) a *dummy* variable $Z_3$ that reflects the *Altimetry* of the farms (1 = mountain; 2 = hill; 3 = plane), 4) and by a *dummy* variable $Z_4$ that reflects the placement (or not) of each farm in a *Less-favoured area* such as defined by the EEC Directive 75/268 (0 = Less-Favourite Area; 1 = non Less-Favourite Area).

## Analysis results

Parameters for the function and inefficiency model were estimated simultaneously. Due to space constraints, the ML estimates of the parameters of the SFP function, given the specification for technical efficiency effects defined by Eq. (3), are not presented. Estimation was obtained using the computer program FRONTIER 4.1, created by Coelli (1996).

### *Hypothesis tests*

Statistical tests are needed to evaluate suitability and significance of the adopted model. Specifically, the nature of the problem suggests conducting two tests on the suitability of hypotheses on technological homogeneity regarding agronomic methods and crops. An appropriate testing procedure is the *Generalised likelihood-ratio test*, which permits the evaluation of a restricted model with respect to the adopted model (Bohrnstedt and Knoke, 1994). The statistic associated with this test is defined as:

$$\lambda = -2\ln\Lambda = -2\left[\ln \frac{L(H_0)}{L(H_1)}\right] = -2\ [\ln L(H_0) - \ln L(H_1)] \tag{4}$$

where $L(H_1)$ and $L(H_0)$ are the log-likelihood value of the adopted model and of the restricted model - specified by the formulated null-hypothesis –, respectively. The statistic test $\lambda$ has approximately a chi-square (or a mixed-square) distribution with a number of degrees of freedom equal to the number of parameters (restrictions), assumed to be zero in the null-hypothesis. When $\lambda$ is lower than the correspondent critical value (for a given significance level), we cannot reject the null-hypothesis.

The first test concerns the hypothesis of technological homogeneity between organic and conventional cereal-growing. The starting hypothesis implies that the two methods are not homogenous bundles of defined technologies ($D_{o/c} \neq 0$). The alternative hypothesis (technological homogeneity) is represented by the alternative null-hypothesis

$H_0 : D_{o/c} = 0$. The value of the likelihood ratio statistic for this restricted model is calculated to be 11.56 and it is significantly higher than 3.84, which is the critical value (at 5% significance level) from the $\chi^2$ distribution (Table 2). Hence, the null-hypothesis of technological homogeneity can be rejected. This null-hypothesis is also rejected assuming a Cobb-Douglas model – that is a restricted form of the Translog specification - for the frontier function ($\lambda = 15.58$). Both test results suggest that organic and conventional farms in the sample would lie on two different frontier production functions and, for this reason, the preferred model would involve two separate models for describing organic and conventional methods. More specifically, the estimated positive and significative sign of the parameter $D_{o/c}$ in both the Translog (0.928) and the Cobb-Douglas (1.007) specifications indicate that the conventional cereal-growing farms are using a more productive technology than organic farms.

The second test on frontier production aims to assess if there is a significant technological homogeneity among the three cereal crops. The null-hypothesis $H_0 : D_w; D_o; D_b = 0$ was not rejected both for the Translog and Cobb-Douglas specifications and, hence, it implies that crop diversity would not be a significant factor in describing technology (a common frontier for the three cereal species).

**Table 2.** Tests of hypotheses for parameters of the pool model adopted

| **Restrictions** | **Model** | **L($H_0$)** | $\lambda$ | $\chi^2_{0.95}$ | **Decision** |
|---|---|---|---|---|---|
| None | Translog | 25.58 | | | |
| $H_0 : D_{o/c} = 0$ | Technological homogeneity (*conventional vs. organic*) | 19.80 | 11.56 | 3.84 | Rejected |
| $H_0 : D_{dw}; D_o; D_b = 0$ | Technological homogeneity (*cereal species*) | 24.07 | 3.02 | 7.82 | Not rejected |
| **Restrictions** | **Model** | **L($H_0$)** | $\lambda$ | $\chi^2_{0.95}$ | **Decision** |
| $H_0 : \beta_{ij} = 0$ | Cobb-Douglas | –26.61 | | | |
| $H_0 : D_{o/c} = 0$ | Technological homogeneity (*conventional vs. organic*) | –34.40 | 15.58 | 3.84 | Rejected |
| $H_0 : D_{dw}; D_o; D_b = 0$ | Technological homogeneity (*cereal species*) | –28.92 | 4.62 | 7.82 | Not rejected |

***Organic and conventional models***

Test results suggest adopting a common frontier for the three cereal species and separate frontier models for organic and conventional technologies. Results for both proposed models are shown in Table 3 in the third and fifth columns, respectively[9].

Several tests on the frontier and on the inefficiency models were conducted to assess suitability of the adopted model for both technologies (Table 4). The first test is relative to the frontier model and it aims to assess if the Translog frontier is an adequate representation for the organic and conventional cereal-growing or, vice versa, the Cobb-Douglas model is more suitable to the data. The null-hypothesis $H_0 : \beta_{ij} = 0$ was not rejected for the organic data, while it was strongly rejected for the conventional sample. It means that the Transolg form is the preferable specification for the conventional data, while the best fit of organic data is obtained by the Cobb-Douglas specification. The

**Table 3a.** ML Estimates for SFP parameters for the organic and conventional data - *continue*

| Variable | Parameter | Conventional | | Organic | |
|---|---|---|---|---|---|
| | | (1) | (2) | (1) | (2) |
| **FRONTIER MODEL** | | | | | |
| Constant | $\beta_0$ | **0.412** *(0.105)* | **0.437** *(0.103)* | **0.120** *(0.118)* | **0.416** *(0.165)* |
| Land area | $\beta_1$ | **0.370** *(0.736)* | **0.399** *(0.725)* | **–0.977** *(0.783)* | **0.834** *(0.069)* |
| Seeds expenditure | $\beta_2$ | **0.296** *(0.708)* | **0.312** *(0.687)* | **0.273** *(0.656)* | **0.049** *(0.063)* |
| Fertilizer expenditure | $\beta_3$ | **0.200** *(0.132)* | **0.198** *(0.134)* | **–0.202** *(0.071)* | **0.102** *(0.008)* |
| Capital | $\beta_4$ | **0.179** *(0.285)* | **0.187** *(0.290)* | **–0.741** (0.336) | **0.050** (0.026) |
| Labour | $\beta_5$ | **0.228** *(0.449)* | **0.239** *(0.452)* | **0.896** *(0.483)* | **0.046** *(0.042)* |
| Other expenditures | $\beta_6$ | **0.211** *(0.177)* | **0.218** *(0.180)* | **–0.093** *(0.338)* | **0.023** *(0.016)* |
| (Land area) x (Land area) | $\beta_{11}$ | **0.690** *(0.222)* | **0.695** *(0.226)* | **–0.109** *(0.182)* | – |
| (Land area) x (Seeds exp.) | $\beta_{12}$ | **–0.843** *(0.308)* | **–0.872** *(0.311)* | **0.415** *(0.264)* | – |
| (Land area) x (Fertilizer exp.) | $\beta_{13}$ | **–0.135** *(0.049)* | **–0.131** *(0.047)* | **–0.018** *(0.031)* | – |
| (Land area) x (Capital) | $\beta_{14}$ | **0.066** *(0.118)* | **0.080** *(0.119)* | **–0.194** *(0.101)* | – |
| (Land area) x (Labour) | $\beta_{15}$ | **0.088** *(0.146)* | **0.084** *(0.144)* | **0.353** *(0.193)* | – |
| (Land area) x (Other exp.) | $\beta_{16}$ | **–0.112** *(0.088)* | **–0.109** *(0.089)* | **–0.053** *(0.061)* | – |
| (Seeds exp.) x (Seeds exp.) | $\beta_{22}$ | **0.353** *(0.125)* | **0.373** *(0.128)* | **–0.142** *(0.116)* | – |
| (Seeds exp.) x (Fertilizer exp.) | $\beta_{23}$ | **0.119** *(0.041)* | **0.118** *(0.039)* | **–0.013** *(0.025)* | – |
| (Seeds exp) x (Capital) | $\beta_{24}$ | **0.054** *(0.100)* | **0.051** *(0.107)* | **0.178** *(0.085)* | – |
| (Seeds exp) x (Labour) | $\beta_{25}$ | **–0.108** *(0.128)* | **–0.103** *(0.129)* | **–0.666** *(0.141)* | – |
| (Seeds exp) x (Other exp.) | $\beta_{26}$ | **0.070** *(0.099)* | **0.066** *(0.101)* | **0.148** *(0.045)* | – |
| (Fertilizer exp.) x (Fertilizer exp.) | $\beta_{33}$ | **–0.017** *(0.009)* | **–0.016** *(0.009)* | **–0.013** *(0.009)* | – |
| (Fertilizer exp.) x (Capital) | $\beta_{34}$ | **–0.047** *(0.035)* | **–0.049** *(0.035)* | **0.012** *(0.014)* | – |
| (Fertilizer exp.) x (Labour) | $\beta_{35}$ | **0.020** *(0.035)* | **0.019** *(0.034)* | **0.011** *(0.017)* | – |

| Variable | Parameter | Conventional | | Organic | |
|---|---|---|---|---|---|
| | | (1) | (2) | (1) | (2) |
| **FRONTIER MODEL** | | | | | |
| (Fertilizer exp.) x (Other exp.) | $\beta_{36}$ | **–0.008** *(0.011)* | **–0.007** *(0.010)* | **0.044** *(0.026)* | – |
| (Capital) x (Capital) | $\beta_{44}$ | **–0.030** *(0.012)* | **–0.025** *(0.011)* | **–0.024** *(0.028)* | – |
| (Capital) x (Labour) | $\beta_{45}$ | **–0.056** *(0.074)* | **–0.065** *(0.074)* | **–0.162** *(0.102)* | – |
| (Capital) x (Other exp.) | $\beta_{46}$ | **0.033** *(0.030)* | **0.035** *(0.033)* | **–0.018** *(0.069)* | – |
| (Labour) x (Labour) | $\beta_{55}$ | **0.038** *(0.063)* | **0.040** *(0.061)* | **–0.020** *(0.106)* | – |
| (Labour) x (Other exp.) | $\beta_{56}$ | **–0.009** *(0.026)* | **–0.009** *(0.026)* | **0.112** *(0.035)* | – |
| (Other exp.) x (Other exp.) | $\beta_{66}$ | **0.008** *(0.010)* | **0.007** *(0.011)* | **–0.047** *(0.015)* | – |

**Table 3b.** ML Estimates for SFP parameters for the organic and conventional data

| Variable | Parameter | Conventional | | Organic | |
|---|---|---|---|---|---|
| | | (1) | (2) | (1) | (2) |
| **EFFICIENCY EFFECTS** | | | | | |
| Constant | $\delta_0$ | **0.104** *(0.493)* | – | **–0.210** *(0.926)* | – |
| Age | $\delta_1$ | **–0.009** *(0.004)* | – | **0.010** *(0.012)* | **–0.059** *(0.141)* |
| Gender | $\delta_2$ | **0.070** (0.065) | **0.087** (0.073) | **–0.186** *(0.295)* | **–0.177** *(0.038)* |
| Altitude | $\delta_3$ | **–0.189** *(0.151)* | **–0.202** *(0.058)* | **–0.228** *(0.075)* | **–0.312** *(0.062)* |
| Less-Favourite Area | $\delta_4$ | **–0.221** *(0.099)* | **–0.277** *(0.091)* | **–0.022** *(0.075)* | **–0.487** *(0.236)* |
| **VARIANCE PARAMETERS** | | | | | |
| $\sigma^2 = \sigma_u^2 + \sigma_v^2$ | $\sigma^2$ | *0.058* *(0.089)* | *0.066* *(0.012)* | **0.508** *(0.102)* | **0.197** *(0.188)* |
| $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ | $\gamma$ | *0.247* *(0.098)* | *0.345* *(0.143)* | **0.999** *(0.001)* | **0.987** *(0.022)* |
| $\gamma^* = \gamma \Big/ \left[\gamma + \frac{1-\gamma}{\pi/(\pi-2)}\right]$ | $\gamma^*$ | 0.475 | **0.593** | **0.999** | **0.954** |
| Log-likelihood function | | **13.394** | **12.668** | **21.851** | **13.162** |
| Mean TE | | **0.901** *(0.115)* | **0.902** *(0.115)* | **0.782** *(0.226)* | **0.831** *(0.119)* |

(1) Adopted Model
(2) Preferred model (*) Difference between means significant at 0.01 *t*-test level ($P = 3.9\text{E}-06$)

**Table 4.** Tests of hypotheses for parameters of two adopted models

| Restrictions | Model | L($H_0$). | $\lambda$ | $\chi^2_{0.95}$ | Decision |
|---|---|---|---|---|---|
| | ***Conventional*** | | | | |
| ***Production Function*** | | | | | |
| None | Translog | 13.394 | | | |
| $H_0 : \beta_{ij} = 0$ | Cobb-Douglas | –36.073 | 98.92 | 32.67 | Rejected |
| ***Inefficiency model*** | | | | | |
| None | Translog | 13.394 | | | |
| $H_0 : \gamma = \delta_0; \delta_1 \ldots \delta_4 = 0$ | No inefficiency effects | –13.812 | 54.41 | 13,40* | Rejected |
| $H_0 : \gamma = \delta_0 = 0$ | No stochastic effects | –18.439 | 63.66 | 5.14* | Rejected |
| $H_0 : \delta_0 = 0$ | No intercept | 12.668 | 1.45 | 3.84 | Not rejected |
| $H_0 : \delta_1 \ldots \delta_4 = 0$ | No firm-specific factors | –13.846 | 54.48 | 9.49 | Rejected |
| $H_0 : \delta_1 = 0$ | No age effect | 12.012 | 2.76 | 3.84 | Not rejected |
| | ***Organic*** | | | | |
| ***Production Function*** | | | | | |
| None | Translog | 21.851 | | | |
| $H_0 : \beta_{ij} = 0$ | Cobb-Douglas | 13.248 | 17.20 | 32.67 | Not rejected |
| ***Inefficiency model*** | | | | | |
| None | Cobb-Douglas | 13.248 | | | |
| $H_0 : \gamma = \delta_0; \delta_1 \ldots \delta_4 = 0$ | No inefficiency effects | –63.152 | 152.80 | 11.91* | Rejected |
| $H_0 : \gamma = \delta_0 = 0$ | No stochastic effects | –22.973 | 72.44 | 5.14* | Rejected |
| $H_0 : \delta_1 \ldots \delta_4 = 0$ | No firm-specific factors | –93.265 | 219.15 | 9.49 | Rejected |
| $H_0 : \delta_0 = 0$ | No intercept | 13.162 | 1.72 | 3.84 | Not rejected |
| $H_0 : \delta_1 = 0$ | No age effect | 11.177 | 4.14 | 3.84 | Rejected |

Translog production frontier for the organic farms is not recommended because it does not satisfy the *monotonicity* condition at the point of approximation.

The other tests are associated with the inefficiency model. The second test is devoted to verify if inefficiency effects are absent from the model. Rejection of the null-hypothesis $H_0 : \gamma = \delta_0; \delta_1 \ldots \delta_4 = 0$ for both organic and conventional data indicates that the specification of a model, which incorporates an inefficiency model, is an adequate representation of these data. The third test concerns the nature of the inefficiency effects (stochastic or not). If the inefficiency effects are not random, parameters $\gamma$ and $\delta_0$ will be zero because the model will be reduced to a traditional mean-response function, in which the explanatory variables are included in the function model[10]. In this case the null-hypothesis was rejected in favour of the stochastic specification for both organic and conventional technologies. The fourth test regards the hypothesis $H_0 : \delta_0 = 0$, where inefficiency effects do not have an intercept. The null-hypothesis was not rejected for both conventional and organic models. In the fifth test, we assessed the influence of the selected variables on the degree of firm efficiency. Testing the null-hypothesis $H_0 : \delta_1; \delta_2; \ldots; \delta_4 = 0$, we can verify if the joint effect of the four selected variables is significant, irrespective of the significance of each variables. The fact that this null-hypothesis was rejected would be taken as confirmation that the selected variables are actually illustrative of the efficiency in both models if taken on the whole. The last test concerns the degree of suitability of the model without age effect. The estimated parameter shows an irrelevant magnitude in both models, suggesting that this variable would be scarcely illustrative of efficiency. The null-hypothesis $H_0 : \delta_1 = 0$ was, however, rejected in favour of involving age effect in the organic model, whether it was not rejected for the conventional data.

Both models were estimated in light of the *t*-test results to obtain the preferred form. ML estimations for the more appropriate model are shown in the fourth and sixth columns of Table 3.

***Structure of production***

Basic features of the production function structure for each group were computed on the basis of parameters estimation. At the point of approximation, both the estimated technologies satisfy the *monotonicity* and *diminishing marginal productivities* properties. Since the Cobb–Douglas coefficients have an elasticity interpretation, the value of the parameters for the organic data can be taken as a measure of elasticity. On the contrary, in the conventional farms the production elasticities were computed using the traditional formula for the estimation of the elasticity of the mean output with respect to the *k*-th input:

$$\frac{\partial \ln E(Y)}{\partial \ln(x_k)} = \beta_k + 2\beta_{kk} x_{ki} + \sum_{j \neq k} \beta_{kj} x_{ji} \tag{5}$$

The production elasticity estimates indicate that *Land* contributed the most to cereal production, both in conventional and organic samples (Table 5). The magnitude is equal to 0.713 in conventional technology and it increases to 0.834 in organic technology. The high elasticity of the land area is not surprising in presence of small size farms because this factor could be considered a "quasi-fixed" input. Therefore, this finding suggests that enlargement of the land area would affect significantly farm productivity. On the other hand, it implies that this productivity increase might be more important in the organic farms than in the conventional ones.

A particularly large difference appears regarding *Fertilizer* expenditure. It should be noted that organic farmers use different kinds of fertilizers and pesticides from those used by conventional farmers. Thus, there is no reason to expect that 1 euro worth of organic pesticide would have the same effect on output as 1 euro of worth of conventional pesticide. On the other hand, it is not stated if this aggregate input contributes mostly in the conventional or in the organic process. Our results suggest that use of fertilizers, pesticides and other chemical products makes an insignificant contribution to production, with respect to other inputs, in the conventional system, whether it is significant in the organic farms. Indeed, organic technology elasticity is, on average, 0.102, i.e. it implies that a reduction of 1% in fertilizers, pesticides, etc. would result in a 0.1% reduction in output. The relative high elasticity in the organic cereal-growing process would be a consequence of their low and non-flexible use in this technology, at least so far as our data is concerned. This conclusion can be drawn observing that expenditure for fertilizers and pesticide in the selected organic farms is, on average, less than in conventional farms, despite the less favourable price associated with the organic technical inputs (Table 1). Owing to its infrequent usage, production tends to be sufficiently sensitive to chemical products.

Returns of scale are slightly increased in the organic system (1.104), while they are substantially at a constant level in the conventional technology (1.017)[11].

**Table 5.** Production elasticities of mean output and Return to scale

| Elasticities with respect to | Conventional | Organic |
|---|---|---|
| Land area | **0.713** *(0.506)* | **0.834** *(0.069)* |
| Seeds expenditure | **0.143** (0.098) | **0.049** *(0.063)* |
| Fertilizer expenditure | **0.013** (0.011) | **0.102** *(0.008)* |
| Capital | **0.012** (0.011) | **0.050** (0.026) |
| Labour | **0.110** (0.074) | **0.046** *(0.042)* |
| Other expenditures | **0.024** (0.010) | **0.023** *(0.016)* |
| **Return to scale** | **1.017** | **1.104** |

### *Technical efficiency and inefficiency effects*

The estimated TEs for conventional and organic practices are, on average, 0.902 and 0.831 respectively. This indicates that organic farmers are less efficient than conventional farmers, relative to their specific frontier technology. However, it does not indicate that conventional farms are more efficient than organic farms to the same degree, because the two practices are situated on different technological frontiers. It only implies that conventional farmers operate closer to their specific frontier than organic farmers.

Since in this study TE scores are calculated as an output-oriented measure, results imply that both farming methods might increase production using the same input bundle. Organic (conventional) farmers would be able to increase output by 16.9% (9.8%) with the present state of technology, using their disposable resources more effectively. These levels correspond to an income increase of 78.77 and 49.51 €/ha for organic and conventional farms, respectively.

In the light of results obtained from the common model, contrary to Oude Lansink et al. (2002) findings, our analysis reveal that the organic farmers are not able to compensate for their technical disadvantage (less productivity) with higher efficiency in input use. An important point is to assess the weight of inefficiency in the production, as to evaluate if an improvement of efficiency could affect significantly the productivity in the organic farms. Analysis of the ratio-parameter $\gamma$ gives information on the TE relevance into the production process. The estimated $\gamma$ is significant at 1% level and it indicates that TE is relevant in explaining output variability in both technologies. On the other hand, the parameter value could not be taken as a measure of the relative contribution of the inefficiency term to the total output variance, but this measure can be obtained by estimation of parameter $\gamma^*$, calculated as described in Table 3. In conventional farms, estimation suggests that 59.3% of the general differential between observed and best-practice output is due to the existing difference in efficiency among farmers, while this value is close to unity (0.954) for organic farms. It suggests that TE might play a crucial role into the factors affecting productivity in the organic process. On the basis of the estimated difference in productivity between observed conventional and organic farms in favour of the former, this indication seems really important. It should indicate that a good part of the gap that separates organic cereal farms to conventional farms in terms of productivity could be reduced if organic farmers use more efficiently their technical inputs.

As regards inefficiency effects, ML estimation shows that all the four (three) variables involved are significant for organic (conventional) production. As expected all variables record a negative sign, implying that an increase in each variable positively affects TE, except for the *Gender* variable in the conventional model. In this process, the positive sign associated with the *Gender* variable indicates that farms managed by female tend to be relatively more efficient. However, despite it is statistically significant, the effect of this variable is weak (0.087). Assignment to a *Less-favoured area* is the factor that mainly affect TE (-0.277) in the conventional cereal-growing. It means that cereal farms sited in a *Less-favoured area* tend, as expected, to be less efficient than other farms. Furthermore, analysis shows that technical efficiency decreases with high *Altitude* level (-0.202). Regarding the organic data, assignment to a *Less-favoured area* is the factor that mainly influences TE (-0.487) in the farms. Significant effects are associated also with *Altitude* (-0.312) and with *Gender* of the farmers (-0.177). In the last case, it implies that male farmers tend to be more able than female farmers under organic management. Finally, estimations indicate that ability of organic farmers tends to increase with their *Age* (-0.059), also if the estimated magnitude suggest that this variable is not very illustrative of inefficiency.

**Policy implications**

Despite conclusive indications, regarding efficacy and suitability, that the current CAP policy on organic farming cannot be reached, analysis results reveal some considerations on policy implications, at least as far as cereal-growing is concerned.

The organic sub-sample used in this analysis is represented by farms that have switched to organic management over the years. Therefore, farmers would have achieved sufficient expertise in organic practices. Nevertheless, estimated TE scores suggest that production is not adequately efficient. As emphasized in the introduction, it is clear that the inadequate efficiency of organic farming could invalidate any policy effort in support and, as a consequence, its development. In light of this, at least three policy indications can be suggested:

(1) The main instrument adopted by the CAP for encouraging organic farming is the temporary financial aid given to farmers within the *Agri-environmental* schemes. This subsidy might help them to compensate for probable falling yields and increasing costs due to conversion. On the other hand, it tends to lose its efficacy in middle and long term if not anchored with rigorous eligibility criteria, such as professional skill of farmers or profitability of farms. As evidenced by Tzouvelekas et al. (2001a) about the Greek situation, too unrestrictive criteria may lead to distorted patterns in farmers. Some farmers – substantially ignorant regards organic methods - could be forced to adopt an organic management, not because of an actual interest in this production, but because of financial subsidies (Pietola and Oude Lansink, 2001; Kerselaers et al., 2005). It is common knowledge that, in reality, this pattern is widespread in Italy, and Sardinia

is no exception (INEA, 1998). The EU is also conscious of the inadequacy of the actual eligibility criteria, and is attempting to review the payment scheme. For example, the future CAP should guarantee a more market-oriented and a more rational support for organic farming, promoting an additional temporary and degressive aid to organic farmers that provide to certify their products (European Commission, 2002a)[12].

In the light of our findings, it is our opinion that another principle could be adopted by the CAP. Indeed, it may be advisable to adjust subsidy components, not only on the basis of crops variety, but also taking into account the geographical and socio-economic characteristics of the area. This study found that altitude and assignment in an economically disadvantaged area are the variables that chiefly affect efficiency in the organic farms. Furthermore, results suggest that efficiency in organic farms is influenced by these variables more so than in conventional farms. Thus, it demonstrates that greater *Agri-environmental* aid should go to areas proven to be not particularly favourable by the environmental point of view or where organic agriculture has been slow to take off.

(2) The estimated efficiency scores in our analysis indicate that organic cereal farms have some structural problems if compared with farms under conventional management. Analysis also indicates that inefficiency affects production in organic farms more than in conventional farms. In all probability, the single *Agri-environmental* subsidy is not sufficient to compensate for the structural inadequacies in organic units. From the perspective of improving efficacy in organic farming policy, integration of *Agri-environmental* aid with other rural development measures could enlarge the disposable mechanism for ensuring rational development of the sector. A possibility could be to provide special terms, in favour of organic farms, in distributing financial aid, granted with specific rural development measures, to support organic farming. For example, measures such as '*Investments in Agricultural Holdings*' and '*Setting up of Young Farmers*' (article 4 and 8 of CE Regulation 1257/99, respectively) could provide increasing aid or credit facilities for organic farms and/or organic management, as priority criterion in selecting beneficiaries. According to the *Action Plan* guidelines, another hypothesis could be to target organic farming as the preferred management option in certain areas, such as the *Less-favoured areas*. Both hypotheses are consistent with the CAP emphasis on issues, such as environmental sustainability, food quality and food safety, agricultural surplus reduction. Furthermore, they would permit possible advances in structural improvements in organic farms and increasing efficiency.

3) As highlighted above, efficacy of policy effort is linked with the specific professional skills of farmers. Farmers that intend switching to organic management must have the right technical and professional competency, so as to manage the activity efficiently. Generally, in areas, such as cereal-growing, conversion to organic practices requires more than slight changes in management. Our analyses suggest that Italian cereal farmers have difficulties in implementing organic management practices, as the inferior technical efficiency reflects. Also, the increasing returns of scale that, on average, characterizes the sample organic farms, represent indicators of these difficulties. It implies that organic farmers encounter greater problems in reaching an optimal productivity scale and, on average, lagged behind with respect to conventional producers. Enhancing professional skills could make farmers more knowledgeable, as regards organic methods, in overcoming these difficulties. As a consequence, a rational policy effort should be directed to enforcing professional training and extension services. Both measures could furnish organic producers with the necessary skills during the implementation

phase to ensure the necessary efficiency in the long-term (Lohr and Salomonsson, 2000). Some of these features have just been implemented into the future CAP. In the *Action Plan* for organic farming the EU recognizes the relevance of enforcing farmers' professional skills through an improvement of the extension service efficacy. It is our sincere hope that the CAP will now actually move towards enhancing professional training and extension service.

## Conclusions

The present study involves a comparative analysis of organic and conventional cereal-growing to evaluate their technical efficiency. Using a stochastic frontier production (SFP) approach, the analysis found that organic practices are, on average, significantly less efficient than traditional methods with respect to their specific technological frontier. Since conventional cereal-growing tends to be more productive than organic production the gap should be interpreted as an absolute advantage of traditional farms over organic ones. Although categorical policy suggestions cannot be reached, some considerations on the efficacy of the present CAP and future perspectives can be identified. Results suggest the enforcing some horizontal measures (professional training and extension services) as to improve the ability of organic farmers, thereby guaranteeing efficiency in the long-term. Furthermore, a revision of eligibility criteria for distributing Community subsidies to organic farmers and their integration with other rural development measures are necessary. However, this study represents only a partial contribution and, as mentioned previously, the results cannot lead to generalization. More empirical research needs to be done to gather further information, for policy implications, on the efficiency of organic farming.

## Notes

1. The Plan was approved after different rounds of consultations and discussions in the European Parliament, Council and stakeholder groups. Results of consultations are reported in European Commission (2002b).
2. TE *output-increasing oriented* measure is greater (less) than the TE *input-saving oriented* measure whenever returns of scale are decreasing (increasing). If returns of scale are constant the two measure coincide (Färe and Lovell, 1978)
3. For a more comprehensive review of the most important methods proposed in literature, we remand to Førsund et al. (1980); Bauer (1990); Battese (1992); Pascoe et al. (2000),
4. The presence of stochastic elements makes the models less vulnerable to the influence of outliers than with deterministic frontier models.
5. The rationale underlying is that the specification of the regression of the second stage conflicts with the assumption that $u_i$'s are independently and identically distributed
6. To facilitate estimation process and following the suggestion made by Battese and Corra (1977), the authors suggest to replacing the parameter γ defined above with $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ because of it can be searched between zero and one and this property permit to obtain a suitable starting value for an iterative maximisation process.
7. On the basis of the Sardinian normative, a farm requires to be entirely cultivated with organic method to be classified as "organic". Therefore, any mixing of technologies (organic and conventional) could be used by farm decision makers.

[8] It urges to be underlined that measurement of output ($Y$) in terms of value would not affect the results in this application due to the fact that organic cereals in the observed sample do not receive a *premium price*.
[9] Obviously, the two models do not involve the parameter $D_{o/c.}$
[10] $\delta_0$ must be zero because the frontier model already involves an intercept
[11] The returns of scale in the organic group is significantly different from the unity at the $\alpha$ = 0.10 level
[12] This issue is already a prerogative of the new CAP, provided by EEC Regulation 1782/2003.

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